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Developments in Audio Networking Protocols

By: Mel Lambert

It's an enviable dream: the ability to connect any piece of audio equipment to other system components and seamlessly transfer digital material in real time from one device to another using the long-predicted convergence between AV and IT. And with recent developments in open industry standards and plug-and-play operability available from several well-advanced proprietary systems, that dream is fast becoming a reality. Beyond relaying digital-format signals via conventional AES/EBU two-channel and MADI-format multichannel connections—which requires dedicated, wired links—system operators are looking for the ability to direct digital material from one location to another by labeling the outgoing stream in such a way that it will be routed only to the targeted input port.

In this way, we will be able to reconfigure complex systems with a few keystrokes rather than having to disconnect and reconnect multiple XLR, DB-25, and assorted physical connectors. Once the physical I/O ports have been selected and assigned a unique network virtual address, a browser-based interconnect scheme can vector outputs from a front-of-house console directly to the corresponding loudspeaker inputs, or a bank of microphone signals to the corresponding console inputs.

A number of existing open-standard and proprietary networking schemes provide reliable connections for live sound systems with I/O counts in the hundreds, and hence are suitable for multi-function performance spaces, music theatre, touring rigs, sports arenas, houses of worship, and the like. This article will consider the more prominent of these current offerings, with an emphasis on their applicability within live sound environments.

OSI layer-based model for AV networks

To understand how AV networks work, it is worth briefly reviewing the OSI layer-based model, which divides protocols into a number of smaller elements that accomplish a specific sub-task, and interact with one another in specific, carefully defined ways. Layering allows the parts of a protocol to be designed and tested more easily, simplifying each design stage. For example, TCP/IP is a popular protocol and the basis for Internet-based systems: IP, the Internet protocol, handles the exchange of data between routers using unique IP addresses that can hence select paths for network traffic; while TCP ensures that the data is transmitted reliably and without errors. Popular Ethernet-based protocols are covered by a series of IEEE 802.3 standards running at a variety of data-transfer speeds and media, including familiar CAT-5/6 copper and fiber-optic cables.

All AV networking involves two primary roles: control, including configuring, monitoring, and device command

Extreme Networks Summit Series AVB-compliant multiport switches.

using a communication protocol via the application layer; and transport, which handles data transfer. Usefully, the OSI model defines seven layers used to frame and transfer data:

1. Physical layer, which describes the network's electrical characteristics.
2. Data link layer, or the logic connection, which defines the type of network and how packets are encoded and decoded.
3. Network layer, which provides switching and routing technologies, utilizing addressing, internetworking, and error handling.
4. Transport layer, which provides data transfer and is responsible for end-to-end error recovery and flow control.
5. Session layer, which establishes, manages, and terminates connections between applications.
6. Presentation layer (or syntax), which formats and encrypts data to be sent across a network.
7. Application layer, which supports application and end-user processes by identifying communication partners, quality of service/QoS, user authentication, privacy, etc.

AVnu-certified BSS Audio Soundweb London BLU-805 for AVB networks.

Layer 1, networking schemes based on physical CAT-5/6 wiring and interconnections, include:

- AES50-2005 (also known as SuperMAC and HyperMAC), promoted by Behringer through its Midas and Klark Teknik brands, but also supported by other vendors. AES50 takes a very different approach to IP-based audio systems by using only Ethernet's physical layer and customized routers for point-to-point data transfer; audio samples are streamed continuously, using Ethernet frames to achieve a far more efficient use of the available bandwidth.
- Aviom A-Net.
- Calrec Hydra2 for broadcast applications.
- Riedel RockNet and MediorNet, based on a proprietary redundant-ring topology.

Layer 2, AoE (Audio over Ethernet)

AVnu-certified Crown DCi Series amplifiers for AVB networks.

schemes that utilize standard Ethernet packets, include:

- AES51-2006, which carries AES3-format audio using ATM (Asynchronous Transfer Mode) over Ethernet.
- AVB/Audio Video Bridging is TSN (Time-Sensitive Networking) using IEEE 802.1 standards (and promoted by AVnu Alliance).
- Calrec Hydra for broadcast applications.
- Cirrus Logic CobraNet, one of the earliest audio-specific protocols.
- EtherSound, licensed for use in a variety of products to provide bi-directional and low-latency transfer of up to sixty-four 24-bit channels at a 48kHz sample rate, together with embedded control and monitoring data.
- Roland REAC.

Layer 3, AoIP (Audio over IP) schemes that use standard IP packets over a distance, include:

- AES67-2013 (formerly code-named AES-X-192), which offers high-performance streaming audio-over-IP, plus planned inter-operability with Audinate Dante; ALC NetworX Ravenna (favored by a number of European firms), LiveWire Wheatnet/IP, Q-LAN, and AVB (via a future Layer 3 mode).
- Audinate Dante.
- QSC Audio Q-LAN.
- Telos/Axia Audio Livewire for broadcast applications.
- Wheatstone/IP, used in a range of broadcast consoles.

Most Layer 1 schemes enable simple point-to-point configurations with no individual addressing of components located on an Ethernet-compliant network, and hence must

use a dedicated infrastructure. Adding Layer 2 and Layer 3 functionality offers enhanced flexibility in terms of user-programmable routing and other interrogation/monitoring capabilities. And control of systems components—maybe muting/unmuting of console outputs, or initialing additional DSP functionality—can be implemented via open-standard or proprietary command protocols using TCP/IP and/or UDP/IP communication; usually, this control data coexists on the same network as audio data. Some Layer 2 systems—for example, CobraNet and AVB—have a limited ability to coexist with other network applications on an Ethernet network, while Layer 3 systems offer maximum convergence by supporting IP networking. (While not a true networking protocol, Optocore carries AES/MADI-compliant signals over fiber-optic links and is favored by several manufacturers, including Yamaha and DiGiCo; Optocore's SANE—Synchronous Audio Networking plus Ethernet—protocol is said to enable synchronous digital audio transfer over standard CAT5/6 cables.)

Studio Technologies Dante-compatible Model 214, 215, and 216 announcer's consoles.

Proprietary versus open-standard protocols

Most current networking schemes are proprietary to their developers and seldom offered to competitive brands. The reasons are obvious. Aside from recovering developmental costs, getting Ethernet-based systems to reliably carry multiple channels of digitized audio, video, and control data is a far-from-trivial exercise—which explains why some first-generation protocols simply dedicated a network to carrying digitized data; by optimizing that single function, low latency and accurate

system synchronization could be guaranteed. As faster switches and cabling became available, companies could offer enhanced bandwidths, but the primary goals of on-time data delivery meant that highly customized, often proprietary protocols were the norm.

Cirrus Logic's CobraNet and Audinate's Dante are both licensed, whereas AVB and AES67-2013 are open standards available to any firm that elects to use them; AVnu certification necessitates AVnu Alliance membership dues and certification fees. Moving beyond the interoperability of CobraNet, Dante offers reduced latency and improved synchronization capabilities and is said to offer a simpler, more user-friendly setup process. To meet low-latency, precise synchronization, and enhanced QoS goals, AVB uses newer Ethernet switches that implement the latest IEEE Ethernet standards.

AES67-2013 IP-based networking

"There are three key elements to consider when designing any open-standard for data networks," says Tim Shuttleworth, a networking expert who helped shepherd AES67-2013 through its gestation and ratification, and currently serves as engineering manager at Renkus-Heinz. "Firstly, how are we going to synchronize the network?—in other words: What is our master clock? Secondly, how do you take audio data and turn it into a payload? And thirdly, how do we ensure that a sound file reaches its destination within a target time? To ensure low latency or 'presentation time' for AES67, we targeted a typical latency of less than 3mS."

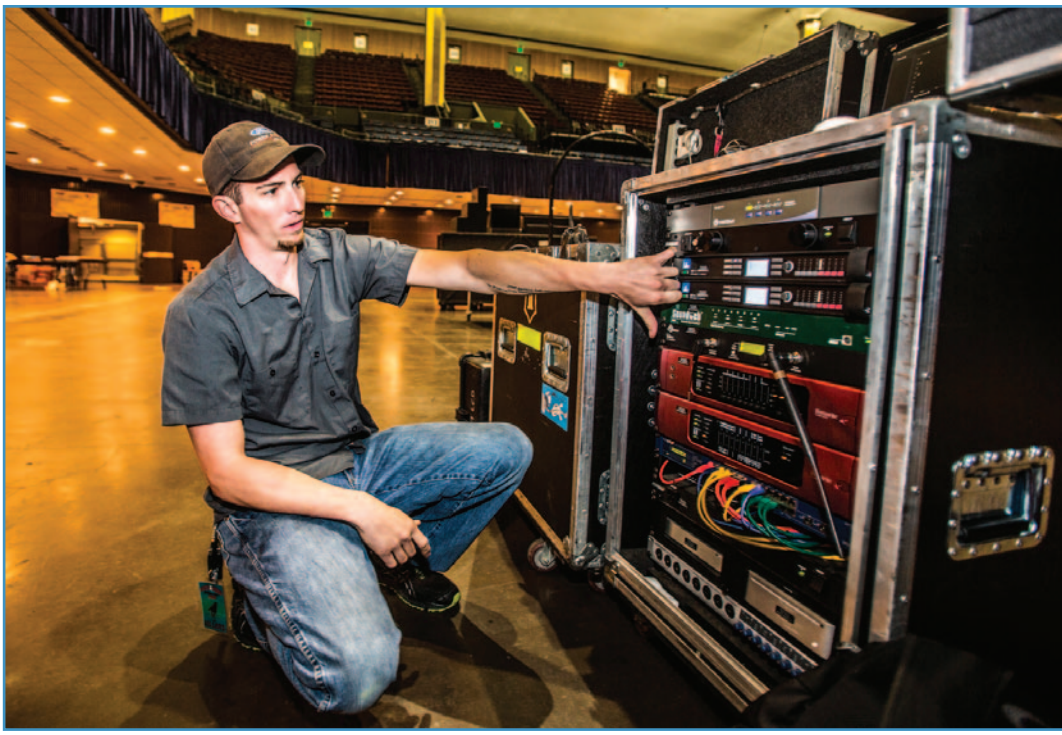
The new AES67-2013 standard provides interoperability recommendations for synchronization, media clock identification, network transport, encoding plus streaming, and session description via high-performance Ethernet switches. The managed network can transmit several hundred stereo channels via a 1Gbit connection, and provides low latency between AES67-compliant devices, with IEEE 1588 being responsible for accurate synchronization; audio clocks sync to a master clock within five seconds of connecting to the network. IEEE 1588-compliant networks nominate a single clock or "grandmaster"—normally the most stable and accurate one; many systems use a GPS-referenced clock—as a master timing reference that is transmitted as a packet of data, known as the PTP message, containing the current time. These messages are used by networked devices to synchronize local clocks with the master. To compensate for round-trip data messaging, IEEE 1588 automatically compensates for any offset.

"Quality of service is essential for any networking scheme, including the new AES67 standard," says Kevin

Gross, current chairman of the AES Technical Committee on Networking and a media consultant with AVA Networks; he worked previously with Peak Audio and Cirrus Logic. “Any standard needs to provide guaranteed delivery of packets of digital audio over a properly configured network.”

While AES67 was originally conceived to include auto-discovery of other AES67-compliant devices on the network, “[that capability] was deleted so that we could publish the standard as soon as possible,” Gross explains. “AES plans to add that ‘I’m Alive Packet’,” adds fellow committee member Shuttleworth. “Under software control, any device can look across the IP-based network and determine which devices are AES-67-capable and available for connection.”

“Personally, I don’t believe that the audio industry should try to solve this problem,” Gross states. “We should convey our requirements and wait for the IT industry to advance the state of



Philip Reynolds, systems engineer for The Killers’ world tour, with Focusrite RedNet data-capable I/O devices.

Soundcraft Vi Series consoles support both AVB and Dante protocols.

discovery protocols. But even though the current version lacks [auto-discovery], AES67 provides reliable multi-channel connections with very low latency. AES67 may be implemented as an interoperability mode or feature on existing devices, in addition to the device's native protocol."

Audio Video Bridging/AVB and AVnu Alliance

Developed by various technical groups within IEEE, Audio Video Bridging has enjoyed a lot of visibility since its advocacy group, AVnu Alliance, was formed during InfoComm 2009 to "provide the specifications that will allow time-synchronized, low-latency streaming services through IEEE 802.1 networks," using IEEE 1722 and IEEE 1733 transport standards. In essence, AVB comprises four key IEEE standards: accurate synchronization of multiple data streams so they arrive at the target device at the correct time; traffic shaping to ensure that data is distributed evenly in time; admission control to tag a data stream and reserve sufficient resources to accurately guide its path from source to destination; and identification of networked devices to ensure AVB compliance. Because of the intelligence brought by this IEEE standard, an AVB network is said to require less complex network engineering.

To date, more than 75 companies have become AVnu Alliance members, including chip-makers Analog Devices, Broadcom, Intel, and XMOS, in addition to Audinate, Avid, Barco, Biamp, Harman International, Meyer Sound, Peavey, Riedel, Sennheiser, and Shure. Because AVB is implemented within the network infrastructure itself, it can co-exist with other networking protocols, including CobraNet, EtherSound, Dante, and Q-LAN, assuming that the non-standard-based protocols can operate within the non-AVB reserved bandwidth. Emergent 10 and 40Gbit AVB-compliant connections will offer sufficient data bandwidth for on-demand multichannel audio, HD video

and companion control data, using either proprietary or open-standard protocols.

One claimed advantage of AVB is that, since hop-to-hop latency through intelligent switches is assured, the protocol can offer a maximum latency of 2mS via up to seven switch hops using 100Mbit links; networks with fewer hops can further reduce that latency. To ensure full interoperability between AVB-branded devices, AVnu Alliance has developed a number of compliance test procedures, including plugfests. AVB-compliant switches are available from several vendors, including Extreme Networks; other brands are expected to follow.

According to Adam Holladay, the firm's marketing manager for systems development, Harman International is currently pursuing an ABCD approach to audio networking, with "A standing for AVB; B for BLU Link, a bus architecture we use with our BSS, dbx, Crown, and Soundcraft components; C for CobraNet, as a legacy scheme; and D for Dante. We're enabling choice by providing integrators and consultants with strong support of comprehensive array of protocols so that they, in turn, can comprehensively address their clients' needs for new projects, legacy projects, or niche projects. Our BSS Audio Soundweb London and Soundcraft Vi Series consoles currently support both AVB and Dante; the Crown DCi Series is the first and—to date—only AVnu-certified amplifier range, and there are a number of Harman products to follow soon."

One criticism leveled against AVB is that, because data packets cannot pass through IP routers, the scheme cannot yet scale, and that routed networks are necessary to create secure paths over wide area networks within large installations—which also are essential for merged networks. However, it can be argued that the requirement to transport media between two or more separated networks typically is not an installation-grade issue and might be considered an uncommon requirement. The AES67 standard's Annex B and Annex C describe how to utilize an AVB network to carry Layer 2 AES67 AV data.

Audinate Dante networking solution

Offering auto-discovery functionality, which automatically identifies any compliant device on the network, Audinate's Dante proprietary protocol is often positioned by its Australian developer as complementing rather than competing with other networking schemes, including AVB; its proponents remain active members of AVnu Alliance. Like Audio Video Bridging and AES67, Dante incorporates IEEE 1588 Precision Timing Protocol that has evolved into AVB's synchronization protocol, and hence is said to provide a smooth transitional path from existing network topologies to AVB standards. Dante licensees include a large number of pro-audio manufacturers, including Allen & Heath, Audio-Technica, Aviom, Behringer, Bose, Crest Audio, DiGiCo, EAW, Electro-

Voice, Focusrite, Harman, Kramer Electronics, Lab.gruppen, Lectrosonics, Peavey, QSC, Sennheiser, Shure, Solid State Logic, and Yamaha.

"Any networking technology takes a while to refine and mature," says Audinate's director of marketing Ervin Grinberg. "Companies are recognizing that the dream of having interoperable products can be achieved today with Dante; OEMs also recognize that it is a better return on their investments to procure networking technologies from experts, rather than dilute their focus. Dante has been in development for about 10 years, and we have worked to deliver a complete networking solution, not just a QoS and time-synch protocol.

"We consider the strengths of Dante to include ease of setup, simple configuration, and best-in-class network health-monitoring tools. Automatic configuration and discovery combine to minimize or eliminate common errors—for example, duplicate IP addresses—which can be very hard to diagnose. Since Dante exploits standard IP networking as much as possible, system designers familiar with IP networking and VoIP, in particular, are very comfortable designing and supporting Dante networks. Dante Controller [software] provides a wealth of information that can be used to manage and troubleshoot a network, including network-wide visibility of clock status and performance, latency monitoring, and warning of network overload. In addition, Dante does not require any specialized switches.

"Dante offers a Layer 3 Audio-over-IP networking transport. While we have completed some engineering development of AVB, market interest for a Layer 2 AVB has dramatically declined and we are waiting to see if there will be a real widespread market demand," the director of marketing explains. "The issues of [AVB-compliant] switches limit the ability to use existing infrastructure, which is not desirable."

Regarding the licensing costs of Dante implementation, "Audinate sells primarily to OEMs, and we do not publicly publish our pricing," Grinberg states. "For OEMs, we provide solutions based on channel requirements, including the cost-effective 2x2 Ultimo interface, Brooklyn II, available with between four and 64x64 channels, a PCIe card that handles 128x128, and a high-channel count [device] for above 128 channels."

But the value of Dante to the OEM and end user is "much more than the hardware port on a box," he stresses. "Companies recognize that Audinate allows them to deploy a premium networking solution that is scalable, interoperable, and has more features than an in-house developed approach; as a result, our OEM base continues to expand. To date, we have licensed over 155 OEMs, with about 60% announced; over 75% of the AVnu Pro-Audio companies are also Dante licensees." To date, Dante has been used in several large sports stadiums, including Twickenham, England;

Tennessee Titan Stadium; and Wells Fargo Arena; the protocol also served as a backbone for such events as the 2010 Olympic Village in London, and Pope Francis I's recent pilgrimage to South Korea.

"We expect AES67 to evolve and new standards to appear as time goes by," Grinberg continues. "But Dante is a media-networking solution, not a format, and has always incorporated standards, as is evidenced by our commitment to support AVB. Support for AES67 could be made available to our OEMs through firmware updates." In February 2014, Audinate announced it would support AES67 by Q1 2015.

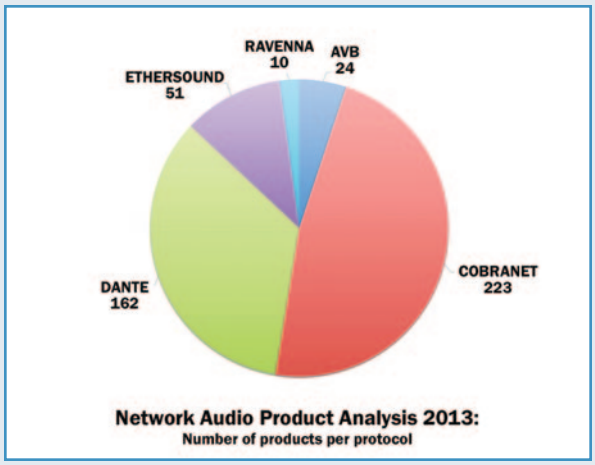
"It is generally accepted that within the US installation market Dante has taken the lead position—and to some extent elsewhere—while Ravenna [in Europe] and Telos [in US] have the lion's share of the broadcast market," Shuttleworth states.

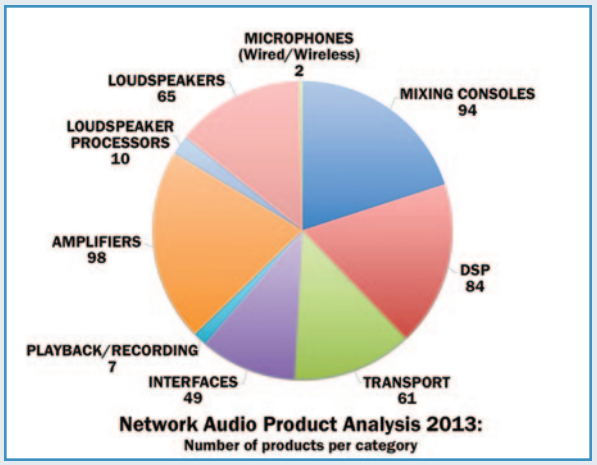
Last year, Focusrite supplied a number of RedNet Dante-compliant interfaces for use on The Killers' world tour, for which a RedNet 1 eight-channel A-D/D-A, and RedNet 4 eight-channel mic pre-amps were used to route digital signals from stage boxes to front-of-house to perform a number of duties for systems engineer Philip Reynolds, who used audio-analysis software and a reference mic to check sound-system response against outputs from the front-of-house console; a pair of Apple Mac Minis—a primary and a backup—connected to the RedNet network using a Dante Virtual Soundcard driver. "With the RedNet 3 providing primary digital connection and RedNet 1 acting as my analog backup," Reynolds recalls, "we [brought down] the latency and kept the quality of audio the same."

"Dante, Ravenna, LiveWire, and our Q-LAN are pretty similar," says Rich Zwiebel, VP of systems strategy at QSC and, while at Peak Audio, inventor of CobraNet. "The differences are just in the details of how they work on network topologies. Since they are all quite similar, it is possible for various manufacturers to modify their offerings and provide an AES67 interface, which will allow products from a large number of manufacturers to interoperate. A unique feature of AES67 is its ability to determine the commonality of devices on a network, and implement a compatibility mode if it 'sees' a Q-LAN-, Dante- or Ravenna-capable device. And AVB is currently Layer 2-based but could be made Layer 3-capable [for larger IP-based networks]. But the elephant in the room is whether or not Cisco, the largest enterprise-level maker of switches—with 80% of the market—will support AVB [with custom-developed devices]. One answer is, why would they, when their profitability is driven by the IT industry?

"Our proprietary Q-LAN handles Layer 3 IP-based commands over 1Gbit LANs, and scales to 10Gbit, to offer 2.5mS latency across seven switch hops, with 512 channels of bi-directional audio transfers. This latency includes A/D, the network, all signal processing, back over the network, and the D/A conversion. It has also been implement-

Market Penetration of Leading Networking Protocols





In early 2014, London-based RH Consulting published a report that analyzed the implementation of various networking protocols in pro-audio products, including live sound systems.

The left-hand figure shows the number of products utilizing the top-five networking protocols, while the right-hand figure shows in which product categories they were being used, ranging from microphones to amplifiers.

Company president/principal audio consultant Roland Hemming reports that his firm is collating research performed during the past 12 months, for a report that will be published by the end of 2014, following the availability in September of a custom application. "The IOS app will allow engineers to find networked products such as 'Dante amplifier' or 'Ravenna mixer'," Hemming states, "and will also list system options. In addition, in-app purchases will allow users to access detailed analysis of our data for product development and market analysis.

"This year's research profiles nearly 800 items—of which 670 are actual products—up from 430 last year. This year we have also included proprietary protocols, and also AES67 compatibility. Comparison with last year's data is tricky because we widened the scope of our research, but there has been a significant increase in networked products.

"While all protocols increased their product count, by far the biggest increase in new products was for Audinate Dante, with over 100 new products this year. It is not always easy to determine if products are discontinued—a particular problem with CobraNet metrics. Although AVB products have shown an increase this year, most of this is because of parts of a single intercom product; in reality, currently there are really only seven AVB product manufacturers. And assuming that Audinate flicks the switch for [AES67 support in] Dante early next year, nearly half of networked products will be AES67-compliant."

More at www.rhconsulting.eu/.

ed successfully within Cisco StadiumVision," a large-scale video and digital content distribution scheme.

While Q-Sys uses Q-LAN between products, it also offers network connections options for CobraNet, AES-3, AES67, AVB, and Dante."

"I expect that as video products with AVB capabilities appear in the market, AV applications with a video requirement will go with AVB, while pure audio in merged networks will go AES67," Shuttleworth concludes.

Author's note: In addition to the people quoted, I'd like to thank the following for their invaluable assistance while researching this article: Lee Minich, engineering manager at Biamp Systems, and formerly marketing work chair of AVnu Alliance; Rich Nevens, director of worldwide professional audio strategy at Avid; Gerry Tschetter, VP of marketing at QSC Audio Products; and Phil Wagner, president of Focusrite Novation.

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